Status of Earth Orbiting Missions

Bryant Cramer

Breakout Session Reports

San Antonio Technology Workshop

Communications IPDT Breakout Group

Gene Fujikawa

May 16, 1996

Participants

• William Rafferty	JPL
• Gene Fujikawa	LaRC
• Ken Perko	GSFC
• Gary Miller	Boeing
• Larry Newman	Lockheed Martin
• Al Grant	Motorla
• Glenn Barney	COMDEV
• Eric Wiswell	TRW
• Rol Chapman	Space Systems/Loral

Outline

1. Summary of positive aspects
   - » Where we are now
2. Perceptions/Problems
   - » How it looks to us 1 year later
3. Recommendations
   - » Where we are headed
   - » How we adapt commercial technology
4. Gaps and Technology Thrusts - Examples

Positives

- Team worked effectively
  - » Handled company proprietary info appropriately
- Developed significant comm technology roadmap
  - » Good feedback on roadmap; influencing other NASA/Gov't Offices
- New metrics and requirements were worked as a team
- Increased understanding of available and emerging comm technologies
- IPDT-endorsed technology has made its way into approved NMP missions
  - » DS1 - HGA, Ka-band SSPA, SDST
  - » DS2 - Transceiver-on-a-chip
  - » EO1 - X-band phased array

Perceptions/Problems

- Small size of NASA space communications technology business base has a limiting effect on industry's interest/participation/investments
  - » Increase synergy between commercial terrestrial/space communications infrastructure/investment and NASA communications technology goals
  - » Work with system architecture (with additional NASA $$) to inject technology
  - » Develop new technology to fill gaps
  - » NMP miniaturization goals exceed current commercial satcom goals
- NMP has overly optimistic view to gain new technology, given cost and schedule constraints
- IPDT process
  - » Need earlier and continuous interaction between IPDT, ADT and Flight teams
  - » Focus on technology gaps and leave mission driven requirements separate
  - » Roadmap was the product of the IPDT

Recommendations

- Minimize NASA unique elements of communications design from mission to mission
- Find convergence of mission requirements and commercial communications technology
- Establish communications technology product lines
  - » Earth observing
  - » Deep space
  - » Planetary networks
- Consider new communications architectures
  - » Deep space gateways
  - » Exploit Ka-band commercial filings
  - » Lower overall cost on ground and technology development

Gaps and Future Technology Thrusts — Examples —

- Optical communications
- Microminiature telecom
  - » Small (~5 kg) telecom subsystem
- Constellations
  - » Needs further architecture study in order to leverage commercial technology
- Breakthrough technologies
  - » MEMS needs technology push
- Deployable, lightweight antennas
  - » Enables use of smaller launch vehicles

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Autonomy IPDT Breakout Group

Carl Adams

May 16, 1996

AGENDA

- Participants
- Process Description
- Breakout Group Reports

Participants

• Guy Man	JPL
• Keyur Patel	JPL
• Ken Lau	JPL
• Roel Van Bezooijen	LMSC
• Reid Simmons	CMU
• Larry Cassidy	Hughes Danbury
• Scott Sawyer	Ames
• Dan Ballard	Reticular Systems
• Rich Doyle	JPL
• John Carl Adams	Stanford
• Stephen Ungar	GSFC
• Bob Twigg	Stanford
• Dan King	USAF - Phillips Lab
• Jess Carlos	Lockheed Tech Operations
• Joe Bushman	CTA Space Systems
• Bruce Bullock	ISX Corporation
• Steve Fox	Eagle-Picher

Process

An open discussion was held to generate ideas and topics for the breakout discussion. Below is the result of this brain storming.

STORMING IDEAS

1. Formation Flying (9)

2. Rendezvous & Landing
   - Site not multi-spacecraft
   - Autonomous navigation and control for rendezvous, landing, and surface exploration

3. Payload data processing
   - Image or other type of science data editing
   - Onbaord event/conditional driven data collection, data processing, editing, and summarization

4. Testing/Simulation (14)
   - Validation plan ((pre-flight)

5. PI Commanded Spacecraft (12)

6. System knowledge capture (11)

7. Flight validation plan (10)

8. Formation flying EO-1 (11)
   - Coordinated flying

Process (cont)

9. Hardware Requirements

10. Engineering Data Processing
    - Appropiate summarization of engineering data for ground use

11. Data Distribution - access to data when needed
    - Having flight data captured and stored and available to scientist and engineers as needed

12. Design process and tools
    - Need new design process and tools to help speed design process

13. Building trust and knowledge between flight and ground
    - Don't need to have people there all the time
    - Have sufficient knowledge and bring in
    - Spacecraft provides explanation for what it did
    - Use real scenarios in testing
    - Use operations personnel in development and test

Process (cont)

Above technology ideas were multi-voted on by the team to identify the areas the team wanted to address. From the voting (outcome in parentheses for the largest vote getters above) a number of topics were combined due to their synergy. These were the topics on formation flying and ground and flight V&V.

1. Formation flying (DS and EO)
   - Understand science requirements
   - Opportunities for formation flying to demonstrate technology
   - Intra spacecraft communications
   - Hardware requirements (sensors, e-net, lan, computer, etc..)
   - Centralized vs. Decentralized (controls, command, etc..)
   - Data management between spacecraft
   - Verification and Validation

2. Ground and Flight Verification and Validation
   - Pre flight V&V
   - Post launch V&V
   - Inflight V&V
   - End of mission experiment

3. PI commanded spacecraft
   - Scientist sends 'Goals' to spacecraft. Perform 'what' commanding instead of 'how'
   - PI requires feedback for the request being sent
   - Support tools (mission design sim)

4. System knowledge capture
   - Consistent models, use same in flight and ground
   - Transferable models between flight and ground
   - Consistent methodology - Incorporate appropriate changes as system matures
   - Tool/process to facilitate knowledge capture
   - Standard/modularity

Formation Flying Problem Statement

- Why fly spacecraft in formations?
- Enable new science missions that require formation flying
  - Multiplatform coordinated observations
  - Large baseline stellar interferometer
- Functional redundancy
  - Reliability, multiple instrument platforms
  - Formations are expandable and adaptable
- Potential cost savings
  - Smaller vehicles, smaller launchers, etc.
  - Less ground operations cost
- Technology validation gap for formation flying for NMP

FF Recommended Approach

- Identify opportunities for formation flying technology validation on EO and DS missions

- EO-1 mission formation flying requirements
  - Co-fly with Landsat-7
  - Repeated ground track accuracy requirement of 1 Km
  - Accurate spacecraft relative ranging not an issue
  - Image co-registration for Landsat thematic mapper validation is driving issue

EO-1 Formation Flying Enhancements

- Ground in the loop - orbit determination and maneuver design, ‘coordinated orbit control’
- LS-7 orbit through TDRSS link eavesdropping
- Ranging with LS-7 retroreflector - on-board EO-1 orbit determination, ‘passive ranging’
- Active formation flying sensor transmitter/receiver on-board LS-7
- Full communication between EO-1 and LS-7

FF Deep Space Missions

- 3 spacecraft free flying interferometer, separated by 100m to 1Km
- 1cm, 1arcmin relative positioning required for science mission
- This mission is a driver for developing precision tightly couple formation flying
- Requires extensive pre-flight validation
  - Simulation
  - Hardware in the loop simulation
  - Ground vehicle formations
  - Aircraft formations
  - Other spacecraft opportunities (LEO experiments, etc.)

FF DS Mission Recommendations

- Ground demo recommendations
  - Hardware in the loop simulations
  - Wheeled vehicle/Aircraft testbeds
- Evolve technical capability
  - LEO mission initially
  - fixed base spacecraft formation determination
  - passive vehicle formation determination
  - active vehicle formation determination and control

FF Conclusions

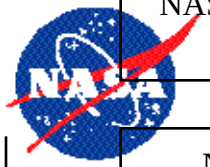
- Go beyond EO-1 mission requirements to really validate formation flying technology
- LS-7 impact would be beneficial to formation flying validation
- Formation Flying is identified as a core technology by the Autonomy IPDT, but...
- If DS3 NMI mission is eliminated, there is a lack of validation of precision formation flying techniques
- There is a need for these technologies beyond validation flights identified - other NASA scientific missions, commercial and military programs

Verification & Validation Problem Statement

- V&V very difficult area to address
- How do we validate and verify autonomy?
- Where do we insert V&V requirements in the NM process?

V&V Recommended Approach

- Identify process for V&V inclusion
- Identify test approach for different phases
  - Pre-flight V&V
  - Post Launch V&V
  - Inflight V&V
  - End of mission experiments



NASA Vision of 21st century

Faster- Better-Cheaper Fleets,
Virtual human presence

NMP Top level requirements

Reduce costs, mass, power operations cost, etc..

Roadmap Generation

Needed capabilities: Autonomy
Program validation criteria: Reduced ops cost

Candidate Technologies

* Optical nav → X% within ground solution
Goal based commanding → Ratio of ground cmds over goal cmds
System requirements - estimates

Tech val criteria

Capability/Technology Evaluation

Technology/Capability and flight selection process

Remote Agent 1 → Flight final exam criteria *

Negotiate readiness

Validation scenario
Validation criteria values
System req (S/C & ops)
Derived cost estimates

Flight Team Experiments

Pass Readiness Gates

V&V Process, including ground final exam *

Flight

Final flight exam

* New additions - see following slides

Process Addition Recommendations(Validation)

- Candidate Technologies
  - Identify all technologies to be evaluated for given mission - including quantifiable benefits and requirements on the flight and ground systems
- Flight Final Exam Criteria
  - Develop detailed test criteria to judge success of technology
- V&V process
  - In addition to other tests perform final exam in ground test and evaluate success against criteria

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µE IPDT
Breakout Group

Jim Wall

May 16, 1996

Agenda

- Participants
- Issues
- Problems/Solutions
- Summary

Participants

Boeing
Warren Snapp
Gary Nelson

JPL
Greg Carr
Savio Chau
Jim Wall

Honeywell
Garry Hubbard

Lockheed Martin
Gerhard Franz

Optivision
Chuck Chalfant

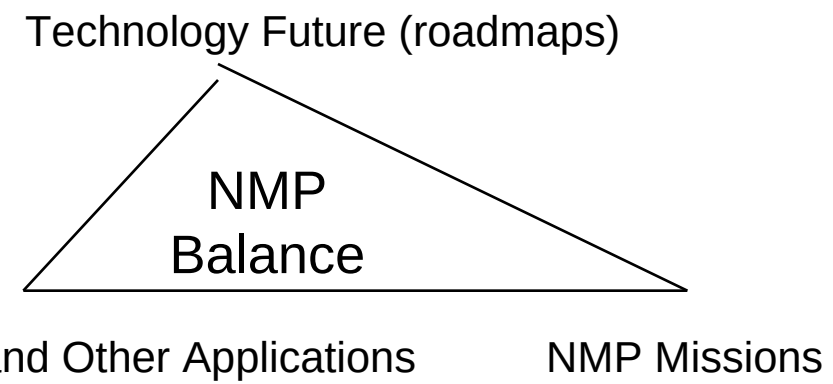
Johns Hopkins/APL
Kim Strohben
Nick Pascholidis

Irvine Sensors
Jack Arnold

Issues

Microelectronics IPDT Products

- Technology roadmaps
  - » needs focus on application to systems in addition to s/c computer & s/c power
  - » Work more with other IPDTs
- H/W & systems in addition to roadmaps
- NMP balance not yet achieved



IPDT Roadmaps

- Used to sell to internal funding sources (IR&D, NMP, etc)
- Encourage funding consortia
- Used to sell to technology users
- Used to plan for future work with technologies
- Should explicitly show technology benefits of interest to users.
- New Idea: “Strategy roadmap” Intersection of several enabling technologies and mission requirements, forming a tech-driven mission design start point.

Validation Flight Technology Selection Criteria

- Change in technology selection criteria (advertised vs actual) over this last year is causing IPDT strain
- Advertised as important at start of NMP
  - » Roadmap-centric selection
  - » IPDT industry member commitment, ($, time,etc)
  - » Leading edge / revolutionary
  - » EO1 was part of mix
- Actually important today
  - » Mission-centric selection
  - » Off-The-Shelf/low-risk
  - » Sales quotient
  - » Cost
  - » EO1 was not part of mix

Issues of IPDT "Sales of Technologies" to NMP

- Find "Sexy" science objectives which need technologies
- Do as much "pre-sales" (sales quotient) as possible
- (on the NMP-side). Have a balanced program which acknowledges mission-driven technology selection, industry-driven technology selection and roadmap-driven technology selection.
- Have more meaningful end-user IPDT interactions
- Package technology correctly
- Make IPDT information publically accessable

Level III technologies; Keep or Not???

- Must have extraordinary payoff
- Won't happen without mission-independent funding
- Recommend two part validation program
  - » Minor league (level III) to take TRL 3/4 to 5/6
  - » Major league (level I & II) to take TRL 5/6 to 8/9
- Real benefit is likely to post-6 NMP validation missions
- Industry sees return for EO stuff more than DS => Level III has biggest contribution to DS missions
- Level III helps with outyear roadmap validity
- Has big leverage with industry partners (if chosen, it turns on big IR&D early)

NMP First Year Technology Selection Observations

- Moving from IPDT input to traditional mission technology selection
- Must get GSFC to participate.
  - » The agreement between NMP and industry partners appears to be broken with EO-1.
  - » NMP money is wasted on EO1 because of no tie to IPDT or its roadmaps => can't show "new millennia" validity of EO1 technologies
- EO-1 puts NMP strategic partnering at risk.
  - » Reality is industry partners have no access to EO missions.
  - » Therefore industry asks "why invest" in the IPDT process if half or more of future missions will be "back room deals"?

IC Brokerage for Radiation Hard MOSIS

- Web page from JHU/APL
- Informal consortium

Ideas for “sexy” missions using our technologies

- 5 kg or less s/c to do constellation-based space physics.
- Relay station missions to form “cosmic information pipeline”
- Piggy-back solar sailors with free rides
- Hyper-spectral science missions

Problems/Solutions

Problem List

- IPDT participation funding
- Mismatch of technology development & mission schedule
- No development dollars available to convert technology to product
- Lack of GSFC and JPL technology selection coordination
- Scalability is good. NASA has trouble getting it.
- Cost-saving technologies which are expensive or take a long time to validate don't make it (can't pass the "mission schedule/cost-cap filter")
- If IPDTs don't deliver hardware, software or systems to flight programs their roadmaps are worthless

Problem Solutions

- IPDT participation Funding
  - » If the IPDT products are needed, then Re Issue study contracts to keep IPDT contributions constant. No funding = No IPDT
  - » IPDT charter needs to be re-established
- Mismatch of tech development & mission schedule
  - » Help some technical validations to be done without NMP validation flights.
  - » Plan & fund to longer horizon than the next flight

Problem Solutions (cont.)

- Investment is needed to intelligently move to faster program cycles
  - » infrastructure tools; small, rapid, non-flight projects
- The connection between technology development in the commercial world and the products needed by New Millennium flights will not occur without sponsorship, i. e. support the roadmaps!
- No development dollars are available
  - » While NMP has little or no “development dollars” it can do a lot as a broker
  - » Some validation dollars have to be available independently from mission dollars
- Lack of GSFC / JPL technology selection coordination
  - » All GSFC participation has been ineffective. We need committment! Or NMP dollars will be wasted on GSFC activity. Program manager intervention is needed

Problem Solutions (cont.)

- The rewards for industry are unclear. A rift has developed between Industry IPDT participation and any recognized reward.
  - » Evidence of renewed committment of NMP to IPDTs and their products
- Scalabiilty is good. NASA has trouble getting it.
  - » Need to design systems with hooks for scalability (and accept the overhead for the "hooks")
  - » Design with correct partitioning
- If IPDTs don't deliver h/w, sw or systems to flight programs their roadmaps are worthless.
  - » Continue and improve IPDT involvement in flight-program hardware development selection and delivery.

Summary

- First 6 months were good. Grade: B+
- In the last 6 months, the program has drifted out of balance (missions/ technologies/the industry). Grade: C
- Industry participation is now flagging. Grade D
- Partnering with GSFC on EO missions is poor. Grade D-
- First year grade: C-
- A lot of work/will power will be needed to get back on-track and ensure the long-range contribution of the NMP.
- Having said all that, the New Millennium Program remains an exciting idea which can still capitalize on much good will.

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MAMS IPDT
Breakout Group

Tosh Fujita

May 16, 1996

Participants—MAMS Group

Name	Organization
Al Schock	OSC
Tim Counts	Eagle Picher
Chris Roberts	CTA
Bob Vondra	USAF/PL
Tosh Fujita	JPL
Brantley Hanks	NASA Langley
Steve Fox	Ithaco

MAMS Technology Scope

- Power
- Propulsion
- Thermal insulation/dissipation
- Cabling
- Heat shield/re-entry
- Structures
- Materials
- Mechanisms
- Vibration isolation
- Landers/rovers
- Penetrators
- Robotics
- Systems analysis/DES methods
- Coolers

Issues-MAMS Group

- Radioisotope Power Systems
- Inflatables
- DOE Membership
- Flight of items that cannot be tested on Earth
  - Precision deployables
  - Precision inflatables (functioning)
  - Manipulator arms
  - Gossamer components

Issues-MAMS Group

- Overcoming conservatism on flight teams
  - Competition between potential flight team leaders
  - Re-evaluate attitudes on Category III
- Target validation flights in R&D planning and funding profiles.
- Maintaining adequate flow of new technology and adequate technology flights.